**Space 2013**

# Cradle-to-Grave Logistic Technologies for Exploration Missions

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Human exploration missions under study are very limited by the launch mass capacity of exiting and planned vehicles. The logistical mass of crew items is typically considered separate from the vehicle structure, habitat outfitting, and life support systems. Consequently, crew item logistical mass is typically competing with vehicle systems for mass allocation. NASA's Advanced Exploration Systems (AES) Logistics Reduction and Repurposing (LRR) Project is developing four logistics technologies guided by a systems engineering cradle-to-grave approach to enable used crew items to augment vehicle systems. Specifically, AES LRR is investigating the direct reduction of clothing mass, the repurposing of logistical packaging, the processing of spent crew items to benefit radiation shielding and water recovery, and the conversion of trash to propulsion supply gases. The systematic implementation of these types of technologies will increase launch mass efficiency by enabling items to be used for secondary purposes and improve the habitability of the vehicle as the mission duration increases.

This paper provides a description, benefits, and challenges of the four technologies under development and a status of progress at the mid-point of the three year AES project.

- The Advanced Clothing System's ground testing of antimicrobially treated exercise clothing and planned ISS DTO will be described. The benefits of moving from cotton based to polymer based clothes with respect to lint production and disposal options and potential increase in flammability will be identified. Additionally, how the reduction in daily clothing mass reduces the benefits of a water laundry system and how it might lead to simpler clothing freshening systems or techniques.
- The Logistics to Living (L2L) concept looks to repurpose items originally used for interior cargo packaging into useful crew outfitting hardware. Cargo items include cargo transfer bags, foam packaging, and stowage racks. This paper will expand on previous work to describe outfitting concepts for crew quarters and solar storm shelters. The L2L technology is actively working with the AES Radiation project to deploy HMC tiles in a cargo transfer bag derived storm shelter concept.
- The Heat Melt Compactor (HMC) processing of plastic containing trash to produce a stable, sterilized, compact tile will be described. The HMC will provide a 10:1 reduction in trash volume which has the capability to increase habitable volume over the course of a mission. Additional benefits of the HMC tile are that it is relatively high in hydrocarbons and useful for solar event radiation shielding. The complexity of the trash stream dictates complex water and gas constituents and tests documenting the major components and life support processing

challenges will be presented. The HMC can reduce the dedicated ration shielding and water resupply masses for exploration.

- The Trash to Supply Gas (TtSG) will summarize early feasibility testing into converting the hydrocarbons in trash to methane for propulsion or a simple gas for airlock free jettison or resistojet station keeping. The TtSG approach would result in large volume reduction of trash and potentially be suitable for planetary missions where preservation of indigenous microorganisms may be important. TtSG has significant technical challenges to achieve robust hardware and significant testing with waste stimulants is underway to identify potential complexities.
- Overall the AES Logistics system analysis has generated an updated Exploration waste model based on current ISS manifest data with accommodations for likely logistics improvements. The major elemental consistency of this trash allows predictions of mission benefits for each of the technologies. The systems analysis aims to develop requirements for logistics providers to enable secondary reuse of their items on-orbit. System analysis will also provide options for logistics and waste management to exploration programs to enable reduced launch mass of dedicated radiation protection material, water, and habitat outfitting.